4.7.6 Relationship among components

In this section, we describe the relationship among the components described in the previous sections based upon several scenarios.

User login

Figure 4.15 shows the mechanism of accessing PAW^2. When a user accesses PAW^2, the Universal AO detects the event (1) and requests the User Manager to create a User Object which manages her (2, 3). Then the User Object accesses a database to retrieve her personal information (4). After storing the information into the User Object, it requests the Agent Manager to create a personal agent for her (5). The Agent Manager checks whether her personal agent already exists in PAW^2 or not (6). If the personal agent does not exist, the Agent Manager creates an Agent AO for her personal agent (7). The Agent AO retrieves the information about the personal agent and stores it into the Agent AO (8). The Agent AO sends an "AddObject" message to all CP browsers via the CP bureau to create a 3D model representing the personal agent (9). After that, the personal agent carries out a "walk" action (10) and walks to a position in front of her owner (11).

Picking up an object

Figure 4.16 shows the mechanism of picking up an object. When a user clicks on an object to pick it up (1), its TouchSensor (see Appendix C) detects the click event and carries out the client-side script of the object (2). The script sends a message to the Object AO which manages the object (3). When the Object AO receives the message, the AO carries out its server-side script to lock the object (4). Next, the script requests the User Manager to release the object to the user (5). The

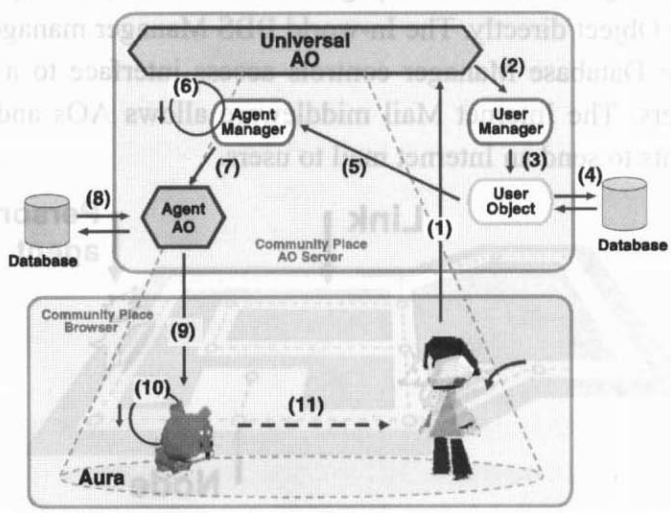

Figure 4.15 The mechanism of accessing PAW^2

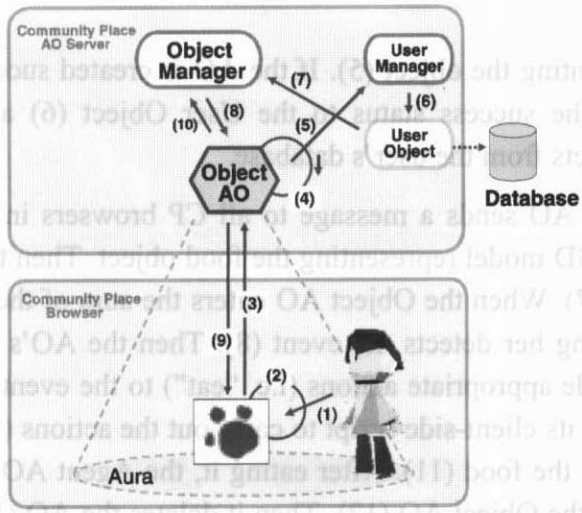

Figure 4.16 The mechanism of picking up an object

User Manager adds the object (i.e. Object ID) to the user's belongings (6). Then the User Object requests the Object Manger to delete the object (7). It deletes the Object AO (8) and the delete message is sent to all CP browsers sharing the object via the CP bureau (9). The Object Manager decreases the number of Object AOs after receiving notification of the deletion (10).

Giving food to a personal agent

Figure 4.17 shows the mechanism of giving food to a personal agent. When a user puts out food in PAW^2, the Universal AO detects the event (1). The Universal AO requests the User Manager to place the food object (2). The User Manager checks the number of the object which the user holds (3). If the user has the object, the User Object requests Object Manager to create the object (4). The Object Manager increases the number of Object AOs in PAW^2 and creates an

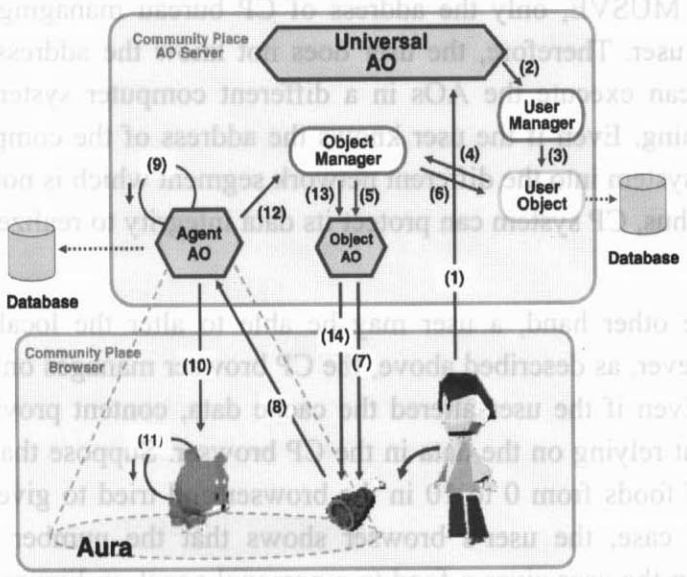

Figure 4.17 The mechanism of giving food to a personal agent

Object AO representing the object (5). If the AO is created successfully, the Object Manager notifies the success status to the User Object (6) and it decreases the number of the objects from the user's database.

The Object AO sends a message to all CP browsers in its aura via the CP bureau to create a 3D model representing the food object. Then the users can see the object in PAW^2 (7). When the Object AO enters the aura of the personal agent, the Agent AO managing her detects the event (8). Then the AO's server-side script is carried out to decide appropriate actions (i.e. "eat") to the event (9). The Agent AO sends a message to its client-side script to carry out the actions (10). In this case, the personal agent eats the food (11). After eating it, the Agent AO requests the Object Manager to delete the Object AO (12). Then it deletes the AO (13) and the object is deleted from all CP browsers (14). Finally, The Object Manager consequently decreases the number of Object AOs.

4.7.7 Security

In CP system, content-dependent data or user data related to the content (e.g. how many objects each user holds) is managed in the following three places: AOs, sub-modules of AOs (e.g. User Object described in Section 4.7.1), or the database accessed by AOs. These three components are referred to as simply "AOs" in this section. Clearly, CP bureau does not know these data. Meanwhile, CP browsers manage only the partial cache of the data. This architecture allows application developers to easily construct secure MUSVE applications.

In case of altering the content-dependent data dishonestly by a user, the user needs to access the AOs directly. However, as described in Section 3.3.4, when a user access a MUSVE, only the address of CP bureau managing the MUSVE is passed to the user. Therefore, the user does not know the address of the AOs. In addition, we can execute the AOs in a different computer system where the CP bureau is running. Even if the user knows the address of the computer system, we can place the system into the different network segment which is not accessible from the Internet. Thus, CP system can protect its data integrity to realize secure MUSVE applications.

On the other hand, a user may be able to alter the local data inside CP browser. However, as described above, the CP browser manages only the cache data of the AOs. Even if the user altered the cache data, content providers can realize service without relying on the data in the CP browser. Suppose that a user changed the number of foods from 0 to 10 in the browser and tried to give it to a personal agent. In this case, the user's browser shows that the number of foods is 10. However, when the user gives a food to a personal agent, in Figure 4.17, the Object

Manager can request the User Manager to check how many foods the user has in the process (3) before creating the AO in the process (4). If the result is 0, the creation is rejected.

4.7.8 Socially-acceptable functions

We need to consider that the flexibility that is provided by the social system has a strong possibility of being used for antisocial behavior which the flexibility makes possible. We will discuss this issue in Section 5.3. To prevent such anti-social behavior, the functions provided by the system should be socially acceptable ones. We call such a function "socially-acceptable function". PAW^2 system provides the following socially-acceptable functions[1]:

- **"Meet" function in a name card system:** This function allows a user to locate the selected user from a name card system and relocate her to the location to meet the selected user (Section 4.4.1). We considered this function is convenient for users to meet other users in a vast virtual world. However, it also allows a user to stalk a specific user. To prevent such a behavior, we do not allow a user to use the function when both the user and the target user do not have each other's name card.
- **Passing an object to other users:** This function can be implemented in two ways: donor-driven method and recipient-driven method. In the donor-driven method, a user selects an item and a recipient to pass it, for example, by clicking the recipient. Then, the recipient's browser will pop up a dialog box to confirm that. In this case, the recipient needs to answer the box even if she does not need the item. We considered that this method is easily used anti-socially to unspecified users and chose the recipient-driven method. In this method, the interaction between two users is carried out as follows:

  (1) A user (referred to as "donor") selects an object and then clicks "pass" button.

  (2) The donor's avatar shows the object to surrounding users in a MUSVE (Figure 4.18).

  (3) A user who needs the object (referred to as "recipient") clicks it.

  (4) Then the donor's browser pops up the dialog box to confirm whether the donor accepts the recipient's request.

[1] In reality, these functions were added after releasing PAW^2 (see Section 5.3).

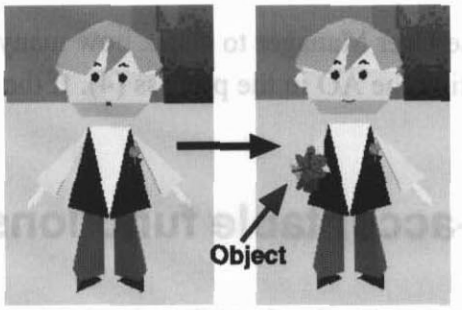

Figure 4.18 An avatar showing an object

(5) When the donor accepts the request, the object is passed to the recipient.

Although unexpected users may click the object, we can reject them by not allowing them to click it when they are enough close to the donor[1].

- **Mute function:** Some users may say unpleasant things to other users. Most communication media have the same problem. We dealt with this problem by providing a mute function (equivalent to a kill file in a USENET newsreader[2]) to enable a user to stop hearing a specific user's chat messages. When a user (user A) selects the troublesome user from a menu in the multi-user window (see Figure 4.1), the PAW^2 system filters out that the user's chat message from user A's browser. As a result, the troublemaker's chat messages are not displayed in user A's browser. Effectively, the troublemaker becomes invisible to user A. If a troublemaker annoys enough users in the community, the troublemaker will end up being totally ostracized[3].

4.8. Evaluation

As we described in Section 4.1, after constructing PAW, we have released it into the Internet to create a virtual world populated by many people. We evaluated it after 8 month passed. In this section, we describe the initial evaluation of PAW and evaluation about new function added to PAW^2.

[1] In VRML, we use a pair of ProximitySensor and TouchSensor to realize this function (Hartman and Wernecke, 1996).

[2] http://www.fau.edu/netiquette/net/manage.txt

[3] Ultimately, we can extend this approach to filter out all information about the troublemaker, including appearance of the troublemaker's avatar.

4.8.1 Methodology

In PAW, we examined PAW's user profile, their characteristics, and PAW's functionalities by using a questionnaire, fieldwork in PAW, and analysis of its database. For the fieldwork, 6 people entered in the world to observe and support novice users for 2 hours during peak access time (from 11 pm[1] to 1 am). Also PAW's database stored user access information, e.g. the number of registered users, login time, and logout time. The following questionnaire was used to evaluate PAW:

- Please state your gender and age.
- Rate the following items on a five-point scale (5 = best, 1 = worst) and comment about them.
  (a) personal agent appearance/functionality, (b) avatar appearance/ functionality, (c) event and game, (d) in-world mail system, and (e) name card[2].
- How many times do you attend the scheduled in-world events?
  (a) always, (b) sometimes, (c) a few times, (d) never.
- How do you get information about the scheduled events?
  (a) official home page, (b) user's home page or mailing list, (c) in-world information (telop), (d) e-mail from a personal agent.
- Do you use other tools with PAW? If so, what do you use? Please list in order of usage frequency.

We gathered 984 questionnaire responses about the evaluation of PAW from normal users.

In PAW^2, we examined user profile, single-user games, in-world mail system, and new functions added to PAW^2's, i.e. in-world BBS system, in-world pager system, and changing avatar color system by using statistical information for four weeks from August 1 1999 to August 29 1999.

4.8.2 Results

We show the result classified in (1) user profile, (2) five-point scale evaluation, (3) events, (4) other tools using together with PAW, (5) single-user

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[1] In Japan, 11 p.m. is the start time for a flat rate access. Most accesses are concentrated from about that time.

[2] This evaluation has been carried out based upon "PAW" (not "PAW^2"). Therefore, this questionnaire does not include the functions added in PAW^2, i.e. in-world pager system, in-world BBS system, and changing avatar color system.

games, (6) in-world mail system, (7) in-world pager system, (8) in-world BBS system, and (9) changing avatar color system.

(1) User profile

Table 4.1 shows the basic statistical information of PAW users based upon the database. It shows that PAW achieved about 300 daily simultaneous user accesses and about 5,000 ~ 6,000 daily accumulated user accesses. In addition, an average length of user's access time is about 3 hours per day.

Table 4.1 User Access Record (5/22/1998 ~ 1/30/1999)

Registered users	32,000
Daily increase of users	About 100~150 increase/day
Number of daily accesses to PAW^2	Max. 7,814 (about 5,000 ~ 6,000 access/day)
Number of daily unique user accesses	Max. 2,042 (about 1,500 ~ 1,600 access/day)
Simultaneous user accesses	Max. 523 (about 300 access/day)
Average length of a user's access time	3 hours /day, Max. 33 hours[1]
Average accesses per a month per user	7 times / month
Number of users who accessed PAW^2 for more than 10 hours	297 (About 1% of registered users)

Figure 4.19 shows the gender ratio and the age distribution of PAW users based upon questionnaire responses. The gender distribution of users was 47% male and 53% female. The age range was from 11 to 48 years, with the mean age of 28.

Figure 4.20 shows the total number of accesses per access time. 11 p.m. is

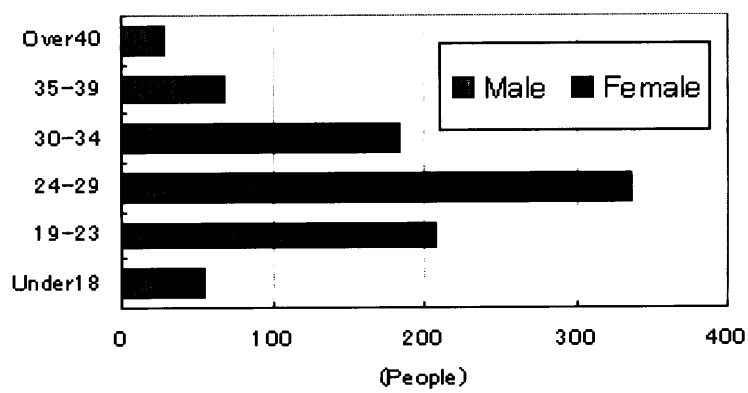


Figure 4.19 Gender ratio and age distribution

[1] PAW and PAW^2 system disconnects a user if the user in non-active for more than 30 minutes. This result means that this user carried out some activities other than connecting to PAW.

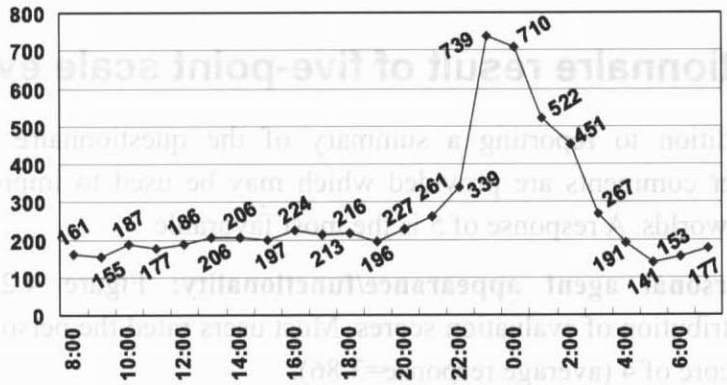


Figure 4.20 Total number of accesses

the start time for a flat rate access in Japan. Figure 4.20 indicates that most accesses are concentrated from about that time. Accesses are also concentrated from Friday night to Sunday.

Figure 4.21 shows the total number of user accesses and unique user accesses in PAW^2. It achieved 6,761 user accesses and 2,066 daily unique user accesses on the average during this duration. Figure 4.22 shows the number of users per accesses to PAW^2. The average accesses per user during the period (29 days) were 17.2 times (11.3 times excluding outliers). The maximum value was 505 times.

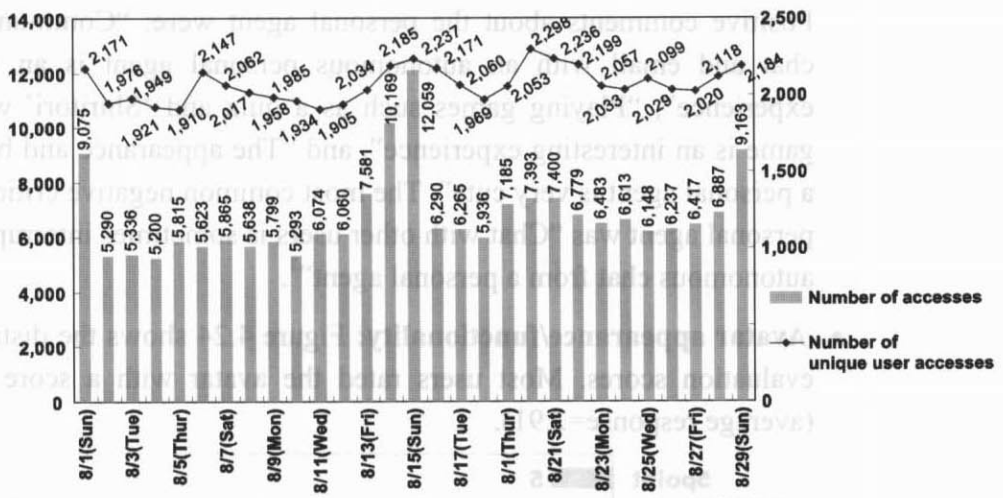


Figure 4.21 Total number of accesses in PAW^2

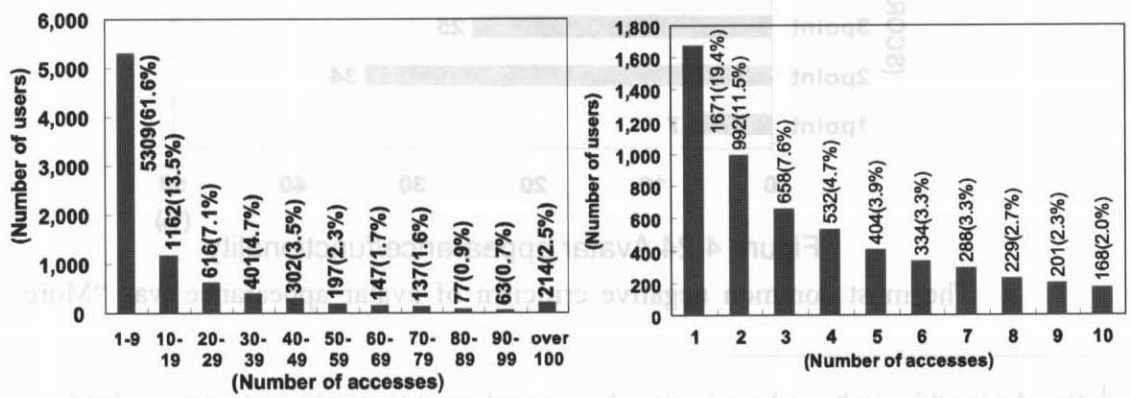


Figure 4.22 Total number of users per accesses to PAW^2

(2) Questionnaire result of five-point scale evaluation

In addition to reporting a summary of the questionnaire results, some additional user comments are provided which may be used to improve PAW and future virtual worlds. A response of 5 is the most favorable.

- **Personal agent appearance/functionality:** Figure 4.23 shows the distribution of evaluation scores. Most users rated the personal agent with a score of 4 (average response=3.86).

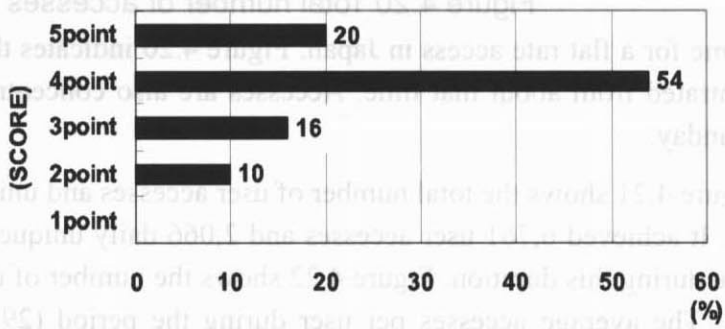


Figure 4.23 Personal agent appearance/functionality

Positive comments about the personal agent were: "Communication by chat and email with an autonomous personal agent is an interesting experience", "Playing games such as a quiz and 'Shiritori' word chain game is an interesting experience", and "The appearance and behavior of a personal agent is very cute". The most common negative criticism of the personal agent was "Chat with other users is sometimes interrupted by the autonomous chat from a personal agent"[1].

- **Avatar appearance/functionality:** Figure 4.24 shows the distribution of evaluation scores. Most users rated the avatar with a score of 2 ~ 4 (average response=2.91).

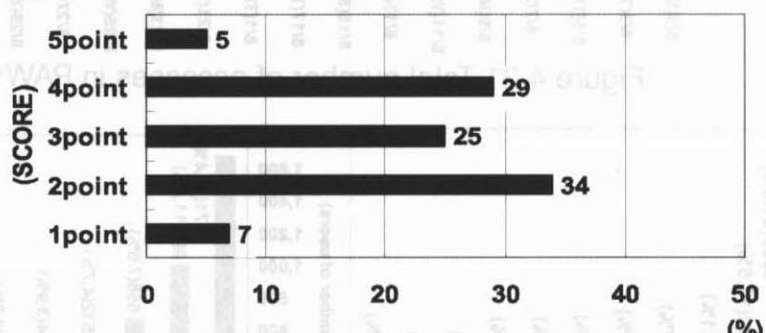


Figure 4.24 Avatar appearance/functionality

The most common negative criticism of avatar appearance was "More

[1] Based upon this result, we have improved a personal agent to stop her autonomous chat for a while by accepting her owner's instruction ("Quiet, please!").

avatar variation and customization are necessary, e.g. functionality to change an avatar's color or attach accessory to the avatar"[1], and "Facial animation such as laughing and getting angry is necessary".

- **Events:** Figure 4.25 shows the distribution of evaluation scores. Most users rated the in-world events and games with a score of 5 (average=3.89).

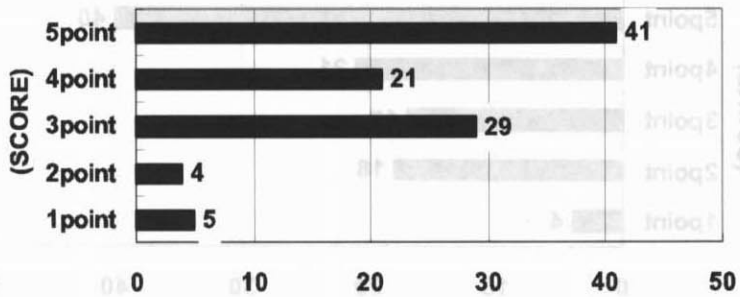


Figure 4.25 Events

Positive comments about the events were "'Search for a cat!' and 'Daruma stacking' events were interesting", and "Growing flowers in virtual environment was an interesting experience". The most common negative criticism of events was "The PAW system becomes heavy due to intensive user access during events".

- **In-world mail system:** Figure 4.26 shows the distribution of evaluation scores. Most users rated the in-world mail system with a score of 4 (average=3.40).

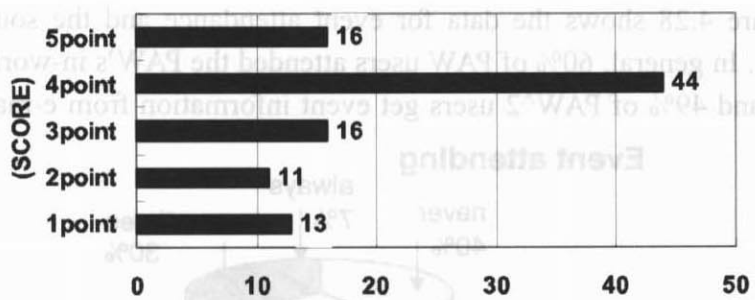


Figure 4.26 In-world mail system

Positive comments about the system were "It is very convenient to send a private letter of gratitude or apology", "It is convenient to communicate with friends whom it is not easily to meet because our access time is different", and "I got a lot of mail with this system, so I'm happy". The

[1] Based upon this result, we have added the function to change avatar color (see Section 4.4.1; Matsuda and Miyake, 2000).

most common negative criticism of event was "More functionality is necessary, such as sorting mail into folders and changing the font size".

- **Name card system:** Figure 4.27 shows the distribution of evaluation scores. Most users rated the name card system with a score of 5 (average=3.43).

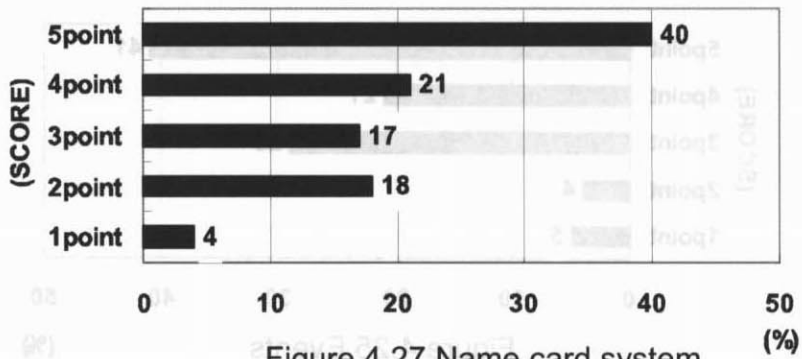


Figure 4.27 Name card system

Positive comments about the system were "I often use the card system to make a friend", "The list of collected name cards makes it convenient to remember a friend's name", and "Exchanging name cards helps start communication with new friends". The most common negative criticism of event was "More functionality is necessary, such as adding a personal memo to the name card".

(3) Events

Figure 4.28 shows the data for event attendance and the sources of event information. In general, 60% of PAW users attended the PAW's in-world event at the same time and 49% of PAW^2 users get event information from e-mail sent by her

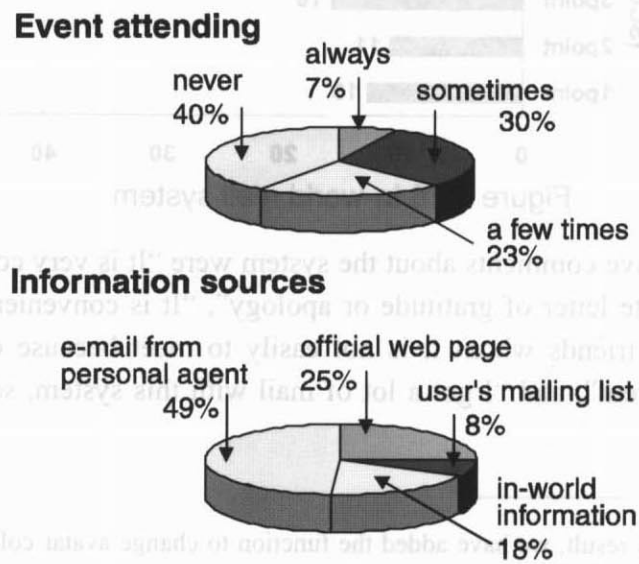


Figure 4.28 Event attending and information

personal agent.

(4) Other tools

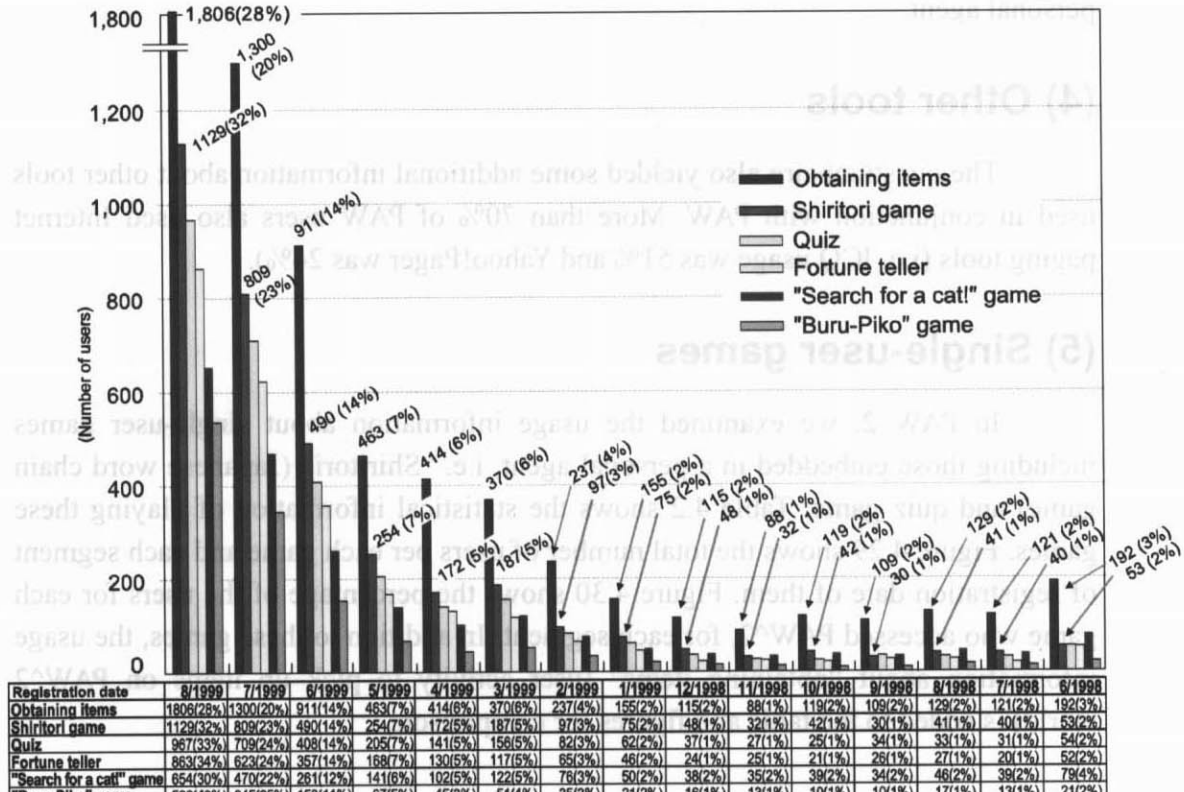
The questionnaire also yielded some additional information about other tools used in conjunction with PAW. More than 70% of PAW users also used Internet paging tools (i.e. ICQ usage was 51% and Yahoo!Pager was 24%).

(5) Single-user games

In PAW^2, we examined the usage information about single-user games including those embedded in a personal agent, i.e. "Shiritori" (Japanese word chain game) and quiz game. Table 4.2 shows the statistical information of playing these games. Figure 4.29 shows the total number of users per each game and each segment of registration date of them. Figure 4.30 shows the percentage of the users for each game who accessed PAW^2, for each segment. In addition to these games, the usage information about "obtaining items" (user activity to pick up items on PAW^2 world) is added to the table and figures for comparison.

Table 4.2 Statistical information on usage of single-user games

"Shiritori" game	Total number of users	11,004 (about 379.4 users/day)
	Total number of times	74,428 (about 2566.4 times/day)
Quiz game	Total number of users	8,156 (about 281.2 users/day)
	Total number of times	80,729 (about 2783.7 times/day)
Fortune teller	Total number of users	6,171 (about 212.8 users/day)
	Total number of times	11,634 (about 401.2 times/day)
"Search for a cat!" game	Total number of users	6,832 (about 235.6 users/day)
	Total number of times	17,742 (about 611.8 times/day)
"Buru-Piko" game	Total number of users	1,972 (about 68.0 users/day)
	Total number of times	3,030 (about 104.5 times/day)
Obtaining items	Total number of users	45,619 (about 1,573. 1 users/day)
	Total number of times	803,656 (about 27,712.3 times/day)



Registration date	8/1999	7/1999	6/1999	5/1999	4/1999	3/1999	2/1999	1/1999	12/1998	11/1998	10/1998	9/1998	8/1998	7/1998	6/1998
Obtaining items	1806(28%)	1300(20%)	911(14%)	463(7%)	414(6%)	370(6%)	237(4%)	155(2%)	115(2%)	88(1%)	119(2%)	109(2%)	129(2%)	121(2%)	192(3%)
Shiritori game	1129(32%)	809(23%)	490(14%)	254(7%)	172(5%)	187(5%)	97(3%)	75(2%)	48(1%)	32(1%)	42(1%)	30(1%)	41(1%)	40(1%)	53(2%)
Quiz	967(33%)	709(24%)	408(14%)	205(7%)	141(5%)	156(5%)	82(3%)	62(2%)	37(1%)	27(1%)	25(1%)	34(1%)	33(1%)	31(1%)	54(2%)
Fortune teller	863(34%)	623(24%)	357(14%)	168(7%)	130(5%)	117(5%)	65(3%)	46(2%)	24(1%)	25(1%)	21(1%)	26(1%)	27(1%)	20(1%)	52(2%)
"Search for a cat!" game	654(30%)	470(22%)	261(12%)	141(6%)	102(5%)	122(5%)	76(3%)	50(2%)	38(2%)	35(2%)	39(2%)	34(2%)	46(2%)	39(2%)	79(4%)
"Buru-Piko" game	536(40%)	345(25%)	153(11%)	67(5%)	45(3%)	51(4%)	35(3%)	21(2%)	16(1%)	13(1%)	10(1%)	10(1%)	17(1%)	13(1%)	21(2%)

(): the percentage of users for each segment per all users played each game

Figure 4.29 The number of users who played single-user game

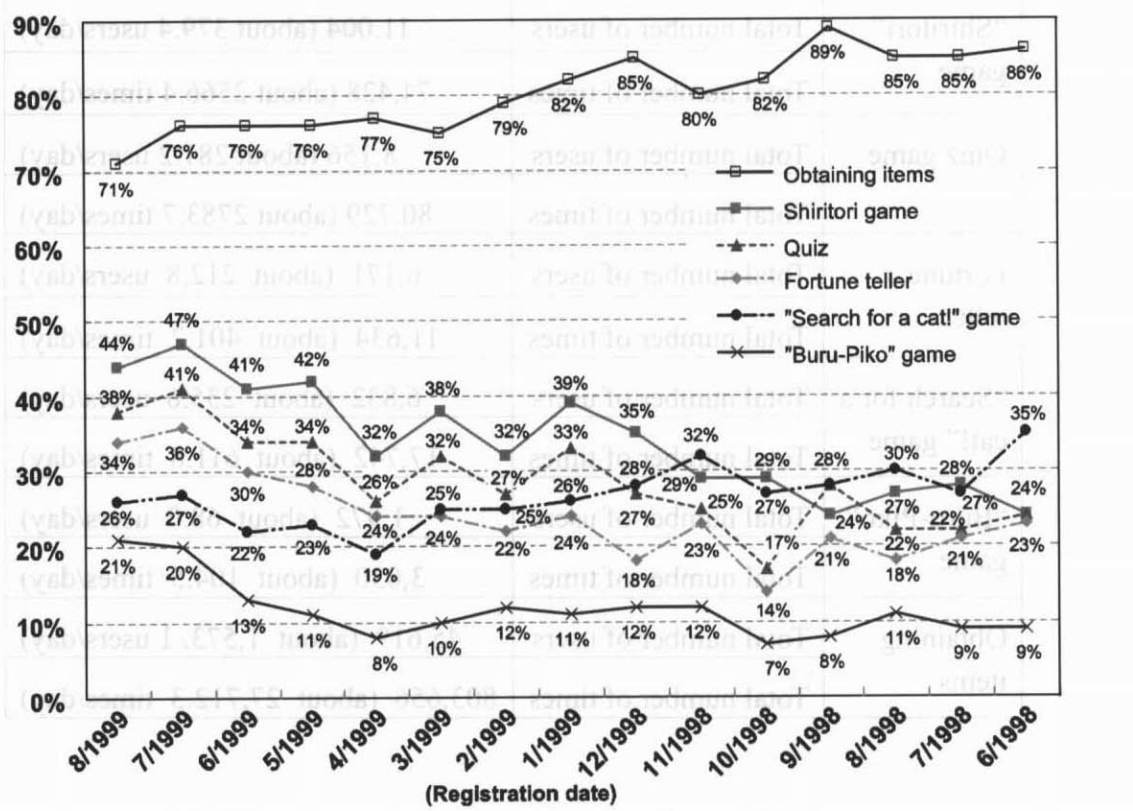


Figure 4.30 The percentage of users who played single-user game

(6) In-world mail system

Table 4.3 shows the statistical information on usage of in-world mail system in PAW^2. The number of unique users accessed PAW^2 during this period were about 2,066 users/day. This number indicates about 15% of users used this system. Figure 4.31 shows the number of people a user sent mail. Its average value was about 3.3 people and the maximum was 120. Figure 4.32 shows that the number of bytes of each message. Its average value was about 392.4 bytes and the maximum was about 1,945 bytes. Figure 4.33 shows the number of in-world mail system users per each registration date of them.

Table 4.3 Statistical information on usage of in-world mail system

Total number of users	8,954 (about 308.8 users/day)
Total number of mails	1,9967 (about 688.5 mails/day)

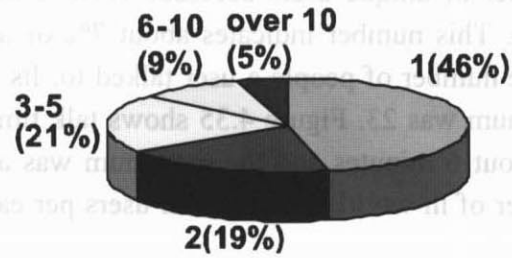


Figure 4.31 The number of people a user sent mail

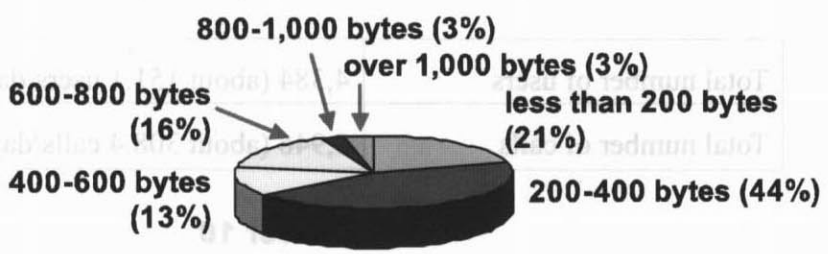


Figure 4.32 The number of bytes of each message

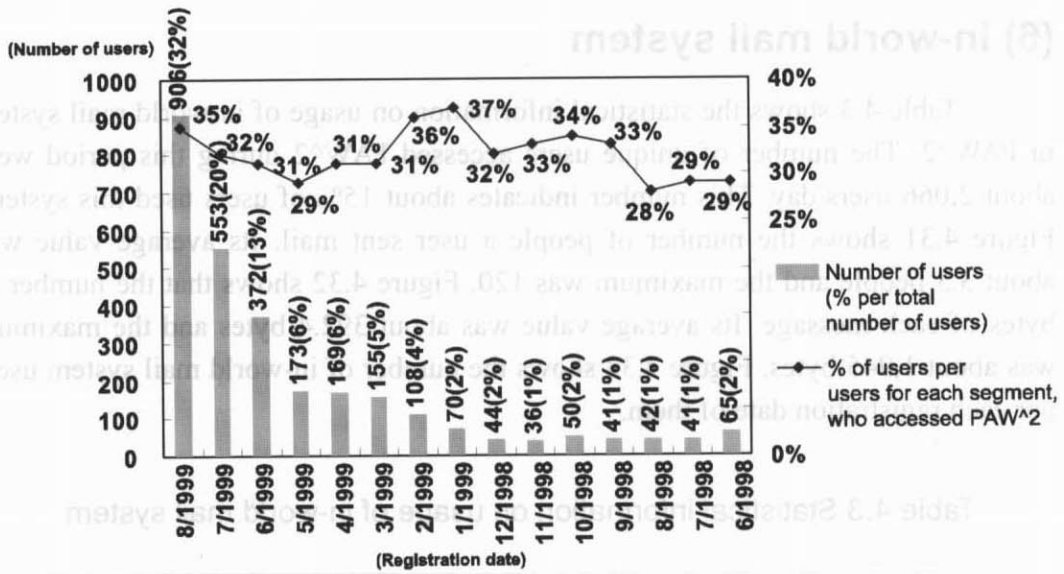


Figure 4.33 The number of in-world mail system users

(7) In-world pager system

Table 4.4 shows the statistical information on usage of in-world pager system in PAW^2. The number of unique users accessed PAW^2 during this period were about 2,066 users/day. This number indicates about 7% of users used this system. Figure 4.34 shows the number of people a user talked to. Its average value was 2.4 people and the maximum was 23. Figure 4.35 shows talk times per one session. Its average value was about 6 minutes and the maximum was about 23 hours. Figure 4.36 shows the number of in-world pager system users per each registration date of them.

Table 4.4 Statistical information on usage of in-world pager system

Total number of users	4,384 (about 151.1 users/day)
Total number of calls	8,946 (about 308.4 calls/day)

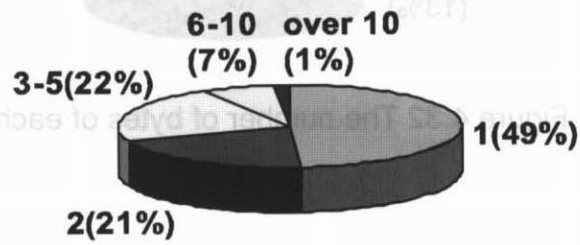


Figure 4.34 The number of people a user talked to

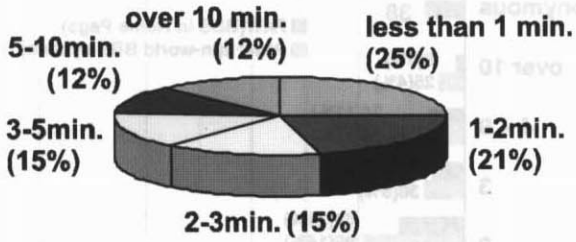


Figure 4.35 The talk times per one session

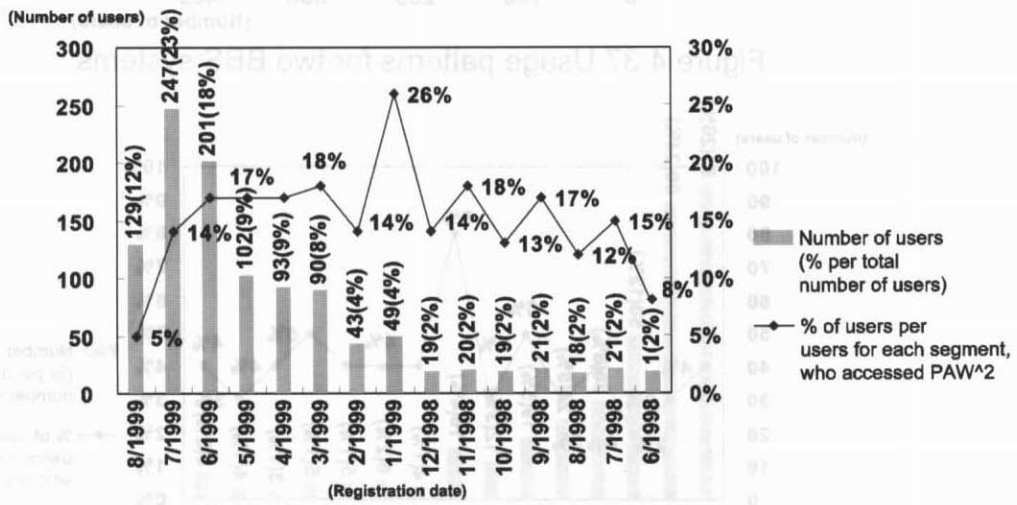


Figure 4.36 The number of in-world pager system users

(8) In-world BBS system

Before providing in-world BBS system in PAW^2, PAW supported BBS system in its home page. Table 4.5 shows the basic usage information about each BBS system for about four months (in PAW^2, from February 10 1999 to May 31 1999). Figure 4.37 shows the number of articles. Figure 4.38 shows the number of users.

Table 4.5 Basic usage information of two BBS systems

	PAW^2 (in-world BBS system)	PAW (BBS in home page)
Daily number of article (average)	13.6	6.6
Total number of article	1,478	748
Total number of users	656	337
Number of article per user	2.3	2.2
User profile	Various types of users	Regular users

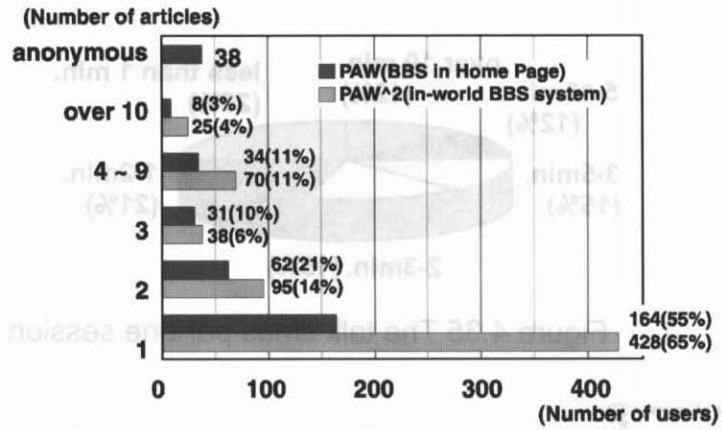


Figure 4.37 Usage patterns for two BBS systems

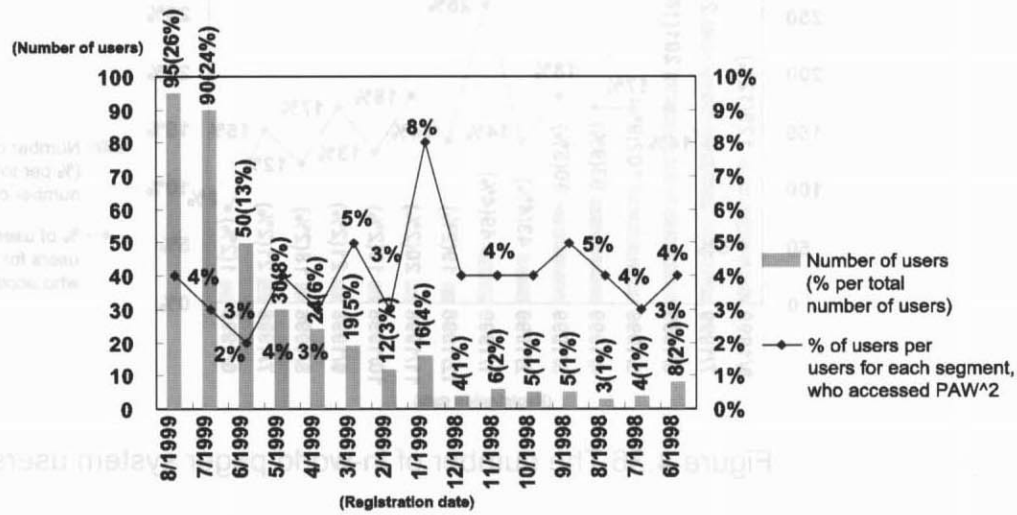


Figure 4.38 The number of in-world BBS users

(9) Changing avatar color system

Table 4.6 shows the statistical information on usage of changing avatar color system in PAW^2. The number of unique users accessed PAW^2 during this period were about 2,066 users/day. This number indicates about 4.5% of users used this system. Figure 4.39 shows the statistics on usage of this system and Figure 4.40 shows the number of users of the system. We observed 538 combinations of color patterns as of June 1996.

Table 4.6 Statistical information on usage of changing avatar color system

Total number of users	2,650 (about 91.3 users/day)
Total number of times	3,200 (about 110.3 times/day)

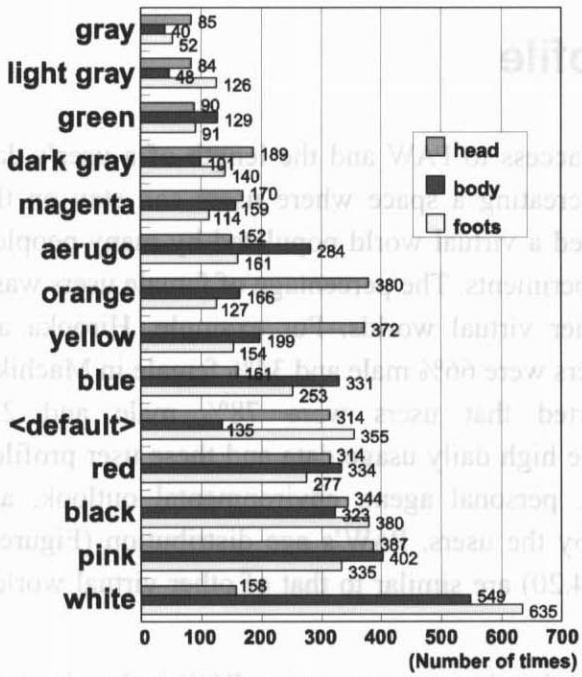


Figure 4.39 Usage of changing avatar color system

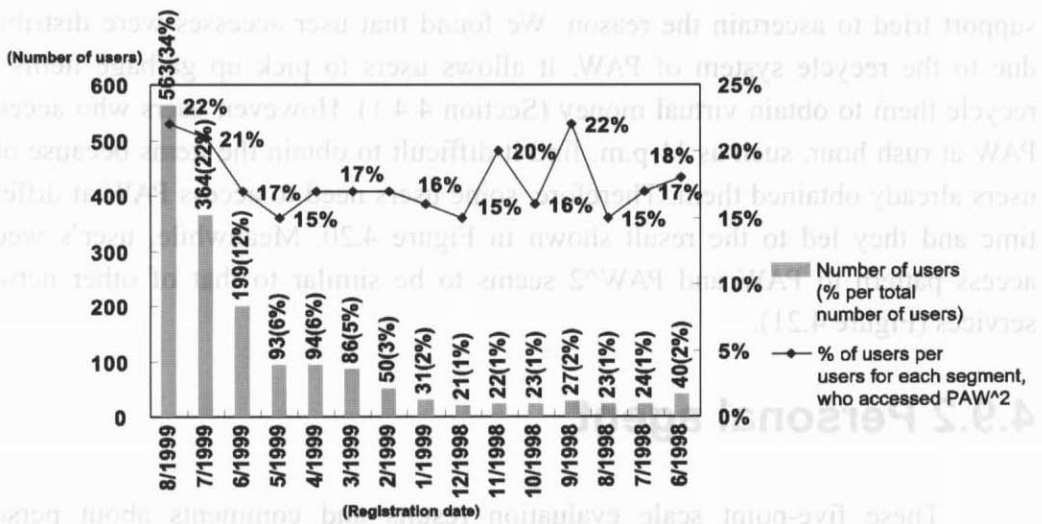


Figure 4.40 The number of changing avatar color system users

4.9. Discussion

According to the results described in the previous section, in this section, we discuss them compared with other virtual worlds in terms of user profile, personal agent, social infrastructure, events, other tools using with PAW, single-user games, and comparison to text/2D-based virtual world.

4.9.1 User profile

The high daily access to PAW and the length of a user's daily access time illustrate that PAW is creating a space where users can stay on the Internet. We successfully have created a virtual world populated by many people which enables us to conduct social experiments. The percentage of female users was observed to be larger than that of other virtual worlds. For example, Hirooka and Tsunematsu (1998) reported that users were 66% male and 34% female in Machiko (Section 2.2). Schiano (1999) reported that users were 78% male and 22% female in LambdaMOO. From the high daily usage data and these user profiles, it seems that our design policy (i.e. personal agent, environmental outlook, and so on) was successfully accepted by the users. PAW's age distribution (Figure 4.19) and user access pattern (Figure 4.20) are similar to that of other virtual worlds (Hirooka and Tsunematsu, 1998).

The interesting point about user access to PAW is that there are always some users in PAW (Figure 4.20), even it is at four o'clock in the morning. Our user support tried to ascertain the reason. We found that user accesses were distributed due to the recycle system of PAW. It allows users to pick up garbage items and recycle them to obtain virtual money (Section 4.4.1). However, users who accessed PAW at rush hour, such as 11 p.m. find it difficult to obtain the items because other users already obtained them. Therefore, some users need to access PAW at different time and they led to the result shown in Figure 4.20. Meanwhile, user's weekly access pattern to PAW and PAW^2 seems to be similar to that of other network services (Figure 4.21).

4.9.2 Personal agent

These five-point scale evaluation results and comments about personal agents are suggested that the personal agent's appearance and functionality were accepted by users. We have successfully introduced a personal agent into a MUSVE. We consider that her behaviors, autonomous communication ability, and ability to play single-user games lengthened the user's access time and increased the chance for her owner to interact with other users. For example, when a user plays quiz, she needs to continue to answer correctly the quizzes provided by a personal agent until she fails. One of top ranking of its result was 240. Since it takes about 10 seconds to answer one quiz, this number indicates that the user stayed PAW^2 world for about 40 minutes to play the game. We can easily consider that the user has more chance to meet other users and also her behavior (i.e. playing quiz) itself shared by other users can provide a conversation cue to them. Figure 4.29 and 4.30 also support that. Figure 4.29 shows more than 60% of total Shiritori users are those whose experience

of PAW^2 is less than three months. Figure 4.30 shows those are more than 40% of users accessed PAW^2 for each segment of their registration date. Playing quiz has also similar tendency. Also we will discuss the influence of a personal agent upon user activities in Section 5.2.

Clearly, the most effective method to promote an event was by e-mail from a user's personal agent (Figure 4.28). These results suggest that the personal agent acts as a link between the PAW^2 world and the user and plays a significant role in information provision. We would utilize this nature of the personal agent to guide users to the specific direction based upon content provider's intention. We can also see the similar tendency about user's reaction to the information provided by an autonomous agent in a single-user guidance application (Kadobayashi and Mase, 1998). They reported that users tended to follow the guidance provided by a guide agent even if they did not need to.

In terms of user's reaction to a personal agent herself, Sumi and others (1998) reported that users had a feeling of intimacy with the character of their human-like guide agent but did not think it was helpful for improving the agent's reliability in their system (C-MAP system). They considered that some users felt too much intelligence or functionality in the system from the human-like appearance of the agent. On the other hand, in ALIVE system, users were more tolerant of imperfections in an agent's perception (such as lags and occasional incorrect and missed recognition) as opposed to that of objects in the virtual world (Maes et al., 1995). They reported that users expected virtual inanimate object to work like an object but they assumed that animal or human-like agent shave perception and states, thus were able to accept that the agent may not have sensed something. In PAW^2, we did not get the similar result about a personal agent to that of the C-MAP system. Users reacted to a personal agent like the ALIVE users did. We consider that the following two points influenced the result: (1) both the balance between appearance and functionality of a personal agent and (2) purpose of the virtual world (i.e. PAW^2) where the agent works. It also shows that our design poly of a personal agent has worked successful. Also from this viewpoint, we consider that we have successfully introduced a personal agent into 3D MUSVE.

4.9.3 Social infrastructure

We discuss the social infrastructure from the following two viewpoints: in-world communication systems and other components.

(1) In-world communication systems

In-world mail system allows PAW^2 users to manage in-world mails within the PAW^2 world based upon their handle name. As can be seen from the comments about the system, sending in-world mail using handle name encourages users to send several types of mail (such as a letter of gratitude or apology) easily. It is obvious that this type of asynchronous communication system is also useful not only in the real world but also in a virtual world. Churchill and Bly (1999) reported that asynchronous interaction provided by MUD system was useful to maintain relationship among users across time. The asynchronous communication in the system is carried out by using the function to log users' conversation. This allows users to read the past conversations carried out in the system later. Also this feature encourages a user to say something to somebody whether or not they are looking, and they will get the message. However, we consider that it is hard to apply this type of logging feature to 3D MUSVE for such asynchronous communication because a degree of privacy of conversations in the environment seems to be higher than that of text-based environment (see Section 5.3.2(8)). We could introduce dedicated rooms which support the logging feature in the virtual world for this purpose.

In other virtual worlds, an agent acts as a mail system. For example, public agent in MUD system called Julia is capable of relaying messages between users (Forner, 1997). Forner reported that it was useful in the system for encouraging user communication. We consider that this is an interesting idea but does not provide scalability to the system in case of receiving many messages from various users. In PAW^2, we utilized a personal agent to notify that her owner has mails using natural language, such as "You have in-world mails. Please click 'mail' button in control panel".

Compared with in-world mail system, we can understand that in-world pager system is used for slightly more private use, i.e. for communication with less number of people (Figure 4.31 and Figure 4.34) and for brief communication less than five minutes (Figure 4.35). However, the percentage of in-world pager users is lower than those of in-world mail system (Figure 4.33 and Figure 4.36). We consider that in-world mail system works a kind of in-world paper system and the paper is used for limited purpose, such as information sharing in events among users in distant locations (see Section 4.9.5).

Table 4.5 illustrates that in-world BBS system received about two times larger number of article than that of BBS system embedded in the home page. It seems to be more useful than traditional BBS system. However, compared with other two communication systems, i.e. in-world mail system and in-world pager system, the percentage of in-world BBS users were lower those of others (Figure 4.33, Figure 4.36, and Figure 4.38). We consider that the convenience to access them

influenced the result. Users can use both the mailer and the pager via a control panel (they can use them anywhere in PAW^2) but need to walk to the access point of BBS system to read/write articles. We might need to consider that the control panel provides the BBS system. However, it would lead to complicated user interface. One interesting point of in-world BBS system is that users who wrote one article were dominant (Figure 4.37). The results of analyzing the content of articles indicate that most of them used this system for their self-introduction. We also observed that most users wrote their article with their number to call them using in-world paper.

(2) Name card system, changing avatar color system, and barter system

In addition to the questionnaire, we investigated how many name cards each user held. A user has 6.6 name cards on the average and maximum number was 1,366. The maximum number indicates that this user gathered 37 name cards per week. We consider that the nature of MUSVE based on avatar and its anonymousness encouraged this phenomenon. Also, "meet" function in the system seems to encourage the tendency because it allows users to easily meet the specified users. The name card system is useful for initiating communication and recalling information about friends in a virtual world. We consider that the system acts as a conversation cue and helps users to establish social relationship among them.

Changing avatar color system is constantly used by the users for all segments (Figure 4.40). It is about more than 15%. Other systems show slightly less percentage of users toward the users who have more amount of experience of the systems. This result indicates that the users do not use the fixed colors of their avatars but change them periodically. Although the users need to walk to the specific area to change avatar color (like in-world BBS system), it shows that about 18% users are fastidious about their appearance. Figure 4.39 indicates that white, pink, red, and black are popular but a family of gray color is unpopular. We consider that more visible colors in PAW^2 world were preferred.

We also understand that PAW^2's barter system contributed to social interaction. In PAW^2's event, users can obtain flowers in PAW^2's summer (Section 4.5). During the summer, for example, we observed that users with a male-type avatar often present roses to female-type avatars in PAW^2 world. We consider that the system is also useful for encouraging users to enrich their social activities in PAW^2.

These kind of social infrastructures are useful to enrich the communication in a virtual environment. We will discuss these social activities in PAW^2 in Section 5.3.

4.9.4 Events

Generally, user's participation of event was high and many accesses concentrated on days when an event was held. The largest number of simultaneous accesses (523 accesses) was also achieved when an event was held. Hosting events are useful to achieve a high simultaneous access rate. The most popular events were a simple game, those which required some navigation in the PAW world, interaction with other users, and making something in PAW world (e.g. spring sowing event). Whereas the least popular events were a difficult game and those which requires long access times to complete the game. Events also seem to contribute shared experience among users and lead to their communication in PAW. We will discuss how user's events and games-related activities influenced user's access behavior to PAW in Section 5.2.

4.9.5 Other tools using with PAW

Most PAW users use Internet paging tools with PAW. These tools are used as a remote communication device to communicate with each other beyond the aura limitation in PAW. For example, if a user needs hints to solve a quiz in an event and user can obtain each hint in several remote places, these tools are used to help to obtain the hints efficiently to solve the quiz using responses from multiple users. This kind of tool is also useful in a virtual world as a social infrastructure[1] to enhance user's social activities.

4.9.6 Single-user games

As described in Section 4.2, we have introduced single-user games to increase the chance that users interact with other users by keeping them in the virtual world for longer. Based upon this goal, we should notice the results from the viewpoint of the users who have less amount of experience with PAW^2, i.e. the left-side segments of Figure 4.29 and Figure 4.30.

Both figures show that the single-user games embedded into a personal agent (Shiritori and quiz game) and fortune teller were attractive among them. We consider that constant support of the personal agent and the nature of 3D MUSVE led to the results. Since the personal agent is provided to each user and is always in front of the user in PAW^2 to provide constant support, users can easily and constantly access these single-user games. The nature of 3D MUSVE allows users to

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[1] Based upon this result, we have added the in-world pager system (Section 4.4.1).

naturally learn how to play them by observing other users play them in the environment. The overall tendency of playing single-user games illustrates that the number and percentage of users for each game are gradually decreasing. This tendency indicates that users have moved from playing single-user games to other activities, such as communication with other users, after finding other users while playing the games. This is because, after making friends, PAW^2 provides tools to directly communicate with them, such as a name card system and in-world mail system. These results indicate that our design policy of introducing single-user games successfully achieved the goal. We will discuss about the transition of user activities in Chapter 5 in detail.

The percentage of users of "Search for a cat!" game (see Figure 4.30) has a slightly different tendency. It is slightly but gradually increasing. We consider that there are fan of this game in the users who have more amount of PAW^2 experience. It is also supported by the fact that the dedicated community for this game was observed in PAW^2 ("Cat hunters", see Section 5.3.2 (1)). It indicates that this game works not only as a single-user game for increasing the chance of interaction with other users but also as a game for fun.

One interesting result which we did not anticipate is that of the "obtaining items" activity. The functionality to obtain items has originally been implemented into PAW^2 for its recycling system. However, its number and percentage of users show high values (Figure 4.29 and 4.30). We consider that this activity also works as a kind of single-user game in a virtual society. In addition, since these items are automatically scattered in the PAW^2 world by the system, users need to walk around in the world to get them. This nature of the activity also can naturally lead to keeping them in the world for a longer time and increase more chances to meet and interact with other users than that of other games necessary to achieve their goal. The percentage of users is gradually increasing. Like the result of "Search for a cat!" game, we also observed the dedicated community for this activity ("Treasure hunter", see Section 5.3.2 (1)).

4.9.7 Comparison to text/2D-based virtual world

Text-based chat worlds, such as MUDs, provide very limited visual stimulation compared to 3D virtual worlds. Of course, text-based worlds and 3D worlds both offers chat capability, but clearly the graphical nature of a 3D world permits the creation of advanced user interfaces like PAW^2's personal agent and shared interactive activities like PAW^2's events. In case of a personal agent, we found that interaction with a personal agent is more natural than text-based agent. In addition, 3D virtual world can provide deeper shared experience than text-based chat worlds (Johnson et. al., 1998). "What I can see is what you can see" is important

nature in a shared environment. It was shown that personal agents and events can offer additional functionality to a world and can enhance the link between a virtual world and the user. These features lead to repeat user visitation and since this is a desirable factor in sustaining a virtual society, 3D worlds could have an advantage over pure text-based worlds. In terms of conversation thread in MUSVEs, multiple threads often go on at the time in the environments. In this case, text-based chat worlds display all text messages in one room in one sequence of messages and users are easily to lose the thread. We can see the similar tendency in 2D-based virtual worlds. To solve the problem, the users need to create and move to "private" rooms for focused discussion. On the other hand, the geographical nature of 3D worlds with AOI algorithm can naturally provide the solution, i.e. what users need to do is to go to different place for the discussion using, for example, "meet" function of name card system.

Meanwhile, 2D-based (2D) virtual worlds provide more visual simulation than the text-based chat worlds. However, Nakanishi and others (1998) reported that the freedom of 3D virtual worlds seems to enable users to relax and that atmosphere may stimulate users into talking easily. We also observed various social and cultural activities in PAW^2 during the evaluation duration. We consider that the freedom of 3D virtual worlds also may simulate users to organize more various social activities than that of 2D virtual worlds. We will describe the social and cultural activities in Section 5.3. In case of supporting a personal agent, we found that 3D virtual worlds can more naturally introduce a personal agent and realize multi-user interaction with her than 2D virtual worlds. In 2D virtual worlds, it is hard to locate a personal agent in the environment. In 3D, as you have seen in PAW^2, we can naturally introduce a personal agent in front of her owner. One solution of this issue in 2D is to place a personal agent overlapped on the underlying window, which was adopted by Helper Agent (Isbister et al., 2000), or avatars. However, in this case, multi-user interaction with the agent in the virtual world is hard to be realized. A bird-type personal agent placed on user's shoulder is another solution. The variety of types a personal agent is advantage in 3D MUSVEs.

4.10. Summary of this Chapter

In this chapter, we proposed a design policy for realizing a virtual society and described its embodiment system called "PAW^2" and its evaluation in the Internet. PAW^2 is a 3D personal agent-oriented virtual society and enhanced past virtual spaces by providing a personal agent and social and environmental infrastructures. The personal agent acts as a user's communication partner and mediator in 3D MUSVE. The personal agent personally supports the user while the user is in PAW^2. The social infrastructure provides an economic system, in-world

communication systems, name card system, and so on. The environmental infrastructure provides four distinct seasons and day and night in the world. Each function in PAW^2 world is implemented as a shared application, i.e. AO, and the AOs are managed by various managers.

After releasing PAW^2 into the Internet, it achieved several hundred of simultaneous user accesses and several thousands of accumulated user accesses daily within 8 months. We preliminary evaluated PAW^2 by using a questionnaire, fieldwork, and its database analysis. The high daily access to PAW^2 and the length of a user's daily access time illustrated that PAW^2 is creating a space on the Internet. The results of questionnaires about a personal agent suggested that the personal agent's appearance, her autonomous communication ability, and ability to play a single-user game were accepted. More than half of users were female and it was observed to be larger than that of other virtual worlds. Events were popular among users and the largest number of simultaneous accesses was also achieved when an event was held. We also showed that in-world communication systems and single-user games works well. These results illustrated that our design policy was successful for our goal.

Based upon these results, we carried out user-oriented evaluations of PAW^2 from various viewpoints. In the following chapters, we will describe them.